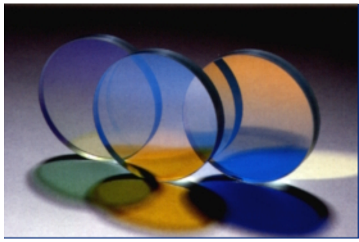


BARR ASSOCIATES, INC.

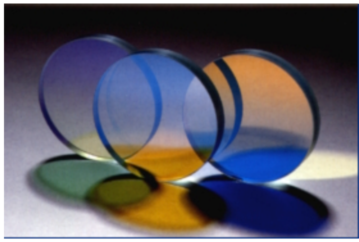
NARROWBAND UV INTERFERENCE FILTER

JUNE 30, 2005

PRESENTED BY:

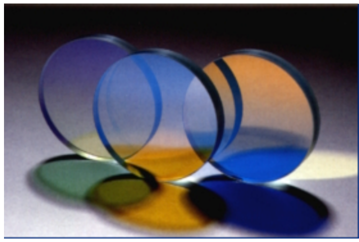
John Potter (Barr Associates)

David Whiteman (NASA GSFC)



OUTLINE

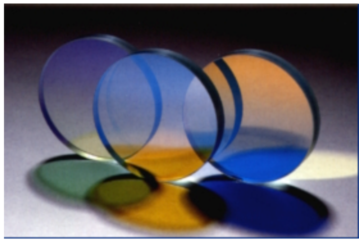
- Objectives
- Specifications
- Research Approach
- Test equipment
- Results
- Conclusion
- Pricing



Objectives

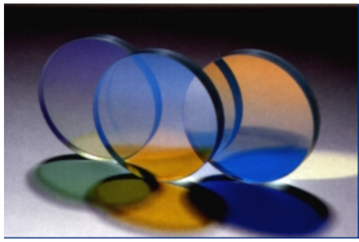
- Conduct fundamental research into improving interference filter technology, to achieve up to twice the transmittance of the previous state-of-the-art technology, while maintaining all other attributes such as out-of-band blocking, size and weight.

- Benefits to Earth Science (Raman Spectroscopy)



Specifications

CWL ± 0.02nm	BW ± 0.05nm	% T	Laser Line Blocking
407.50	.25	> 70%	OD 12 @ 354.7nm; OD 8 @ 375-387nm; OD 9 @ 532, 1064nm
355.23nm (to be used also at 355.10)	.20	> 40%	OD 8 @ 354.7nm; OD 9 @ 532, 1064nm
355.96nm (+.04-0) to be used at 9° AOI	.20	> 40%	OD 8 @ 354.7nm; OD 9 @ 532, 1064nm
386.68	.10	> 60%	OD 12 @ 354.7nm; OD 9 @ 532, 1064nm
386.68	.20	> 70%	OD 12 @ 354.7nm; OD 9 @ 532, 1064nm

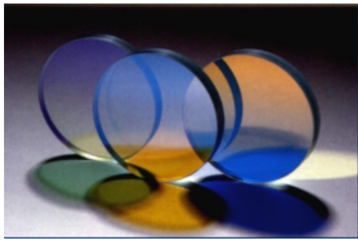


Research Approach

- Process Comparison
- Material comparison
- Minimizing absorption
- Minimizing scatter
- Minimizing reflection losses

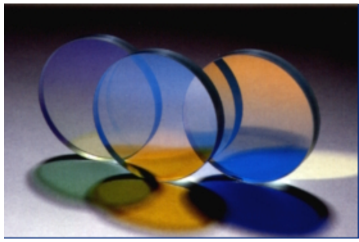
Testing Equipment

- Cary 500 dual-beam spectrophotometer (F/8 beam)
  - 10E-6 (must open slits)
- SPEX 1700 spectrometer (collimated light) for in-band
- McPherson 1-meter for in-band
- Veeco Profilometer (surface roughness)



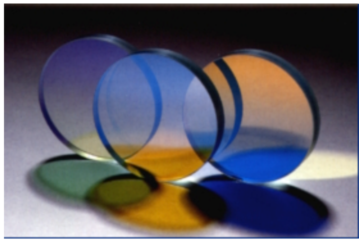
Substrate Surface Roughness vs. Transmittance (minimizing scatter)

B-270 Polished	15.3 Angstroms R.M.S.	43% T @ 371 nm
UV Fused Silica Polished	11.8 Angstroms R.M.S.	56% @ 371 nm
Soda Lime Glass Float	4.8 Angstroms R.M.S.	73% @ 371 nm



Transmittance as a Function of Absorption & Bandwidth

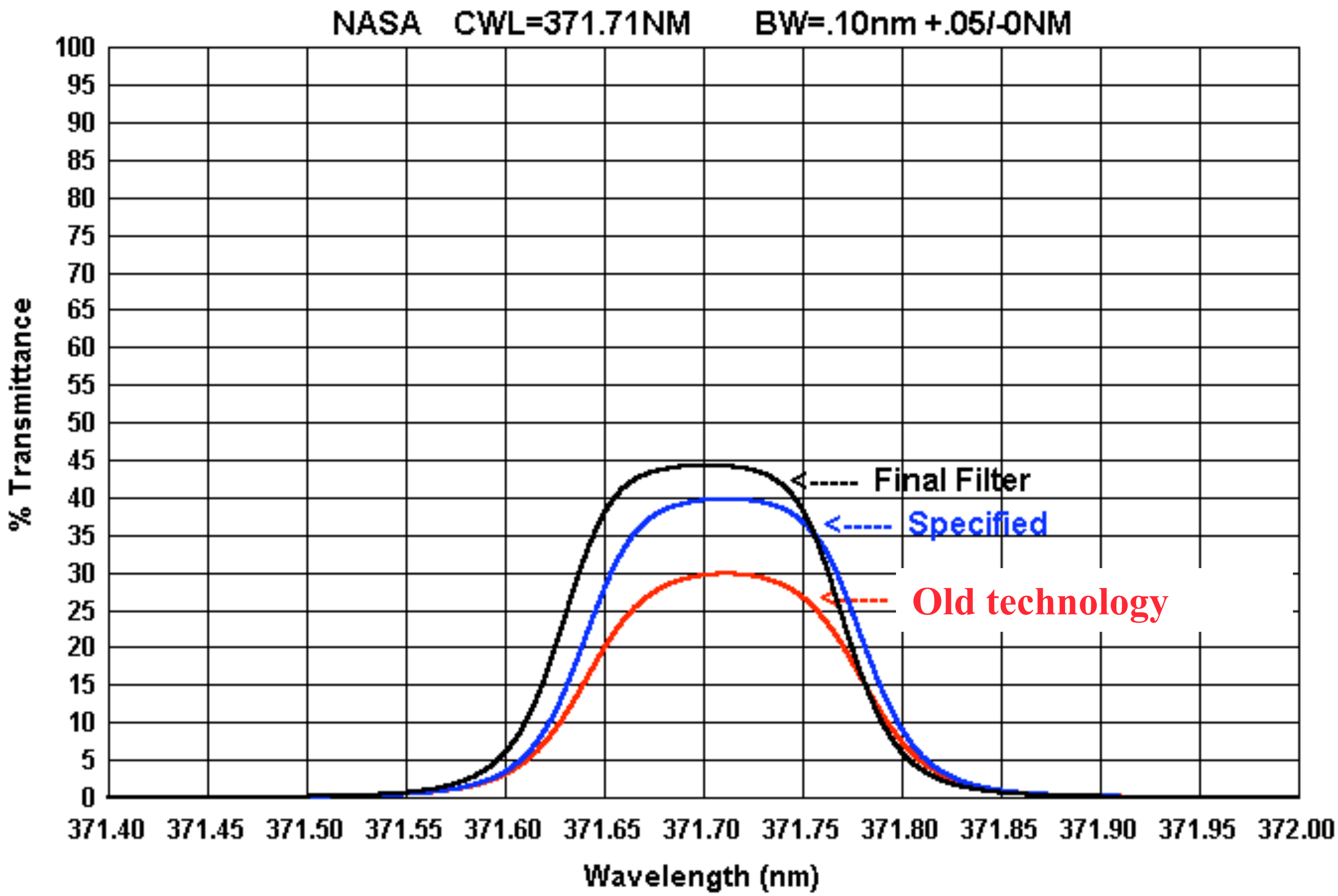
FWHM (nm)	Original Process (T)	New Process (T)
0.04	7.4%	56%
0.06	27%	77%
0.10	41.2%	83.6%
0.20	59.4%	89.8%
1.4	93.3%	98.2%
3.5	97.9%	98.9%



Minimizing Transmission Loss

- Best result was from Improved IAD process compared to Magnetron sputtering & IBS.
- Minimize absorption in layers within highest Electric Field. Best result was from Improved IAD process compared to Magnetron sputtering.
- Less scatter loss with float glass compared with Polished glasses

Result for 371.7/.10nm Filter



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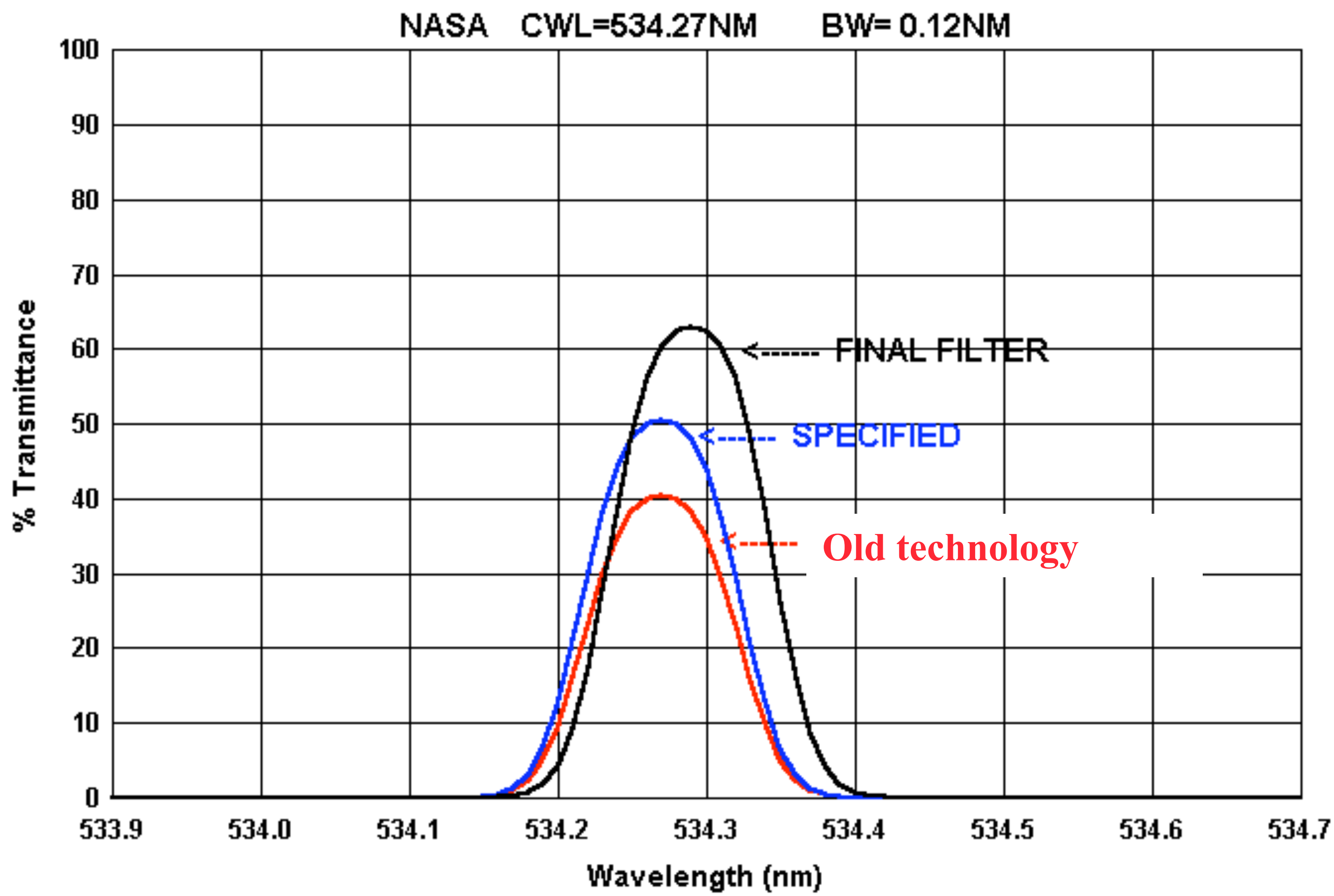
Result for 534.27/.12nm Filter



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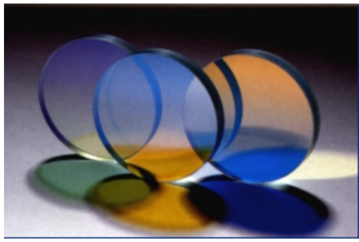
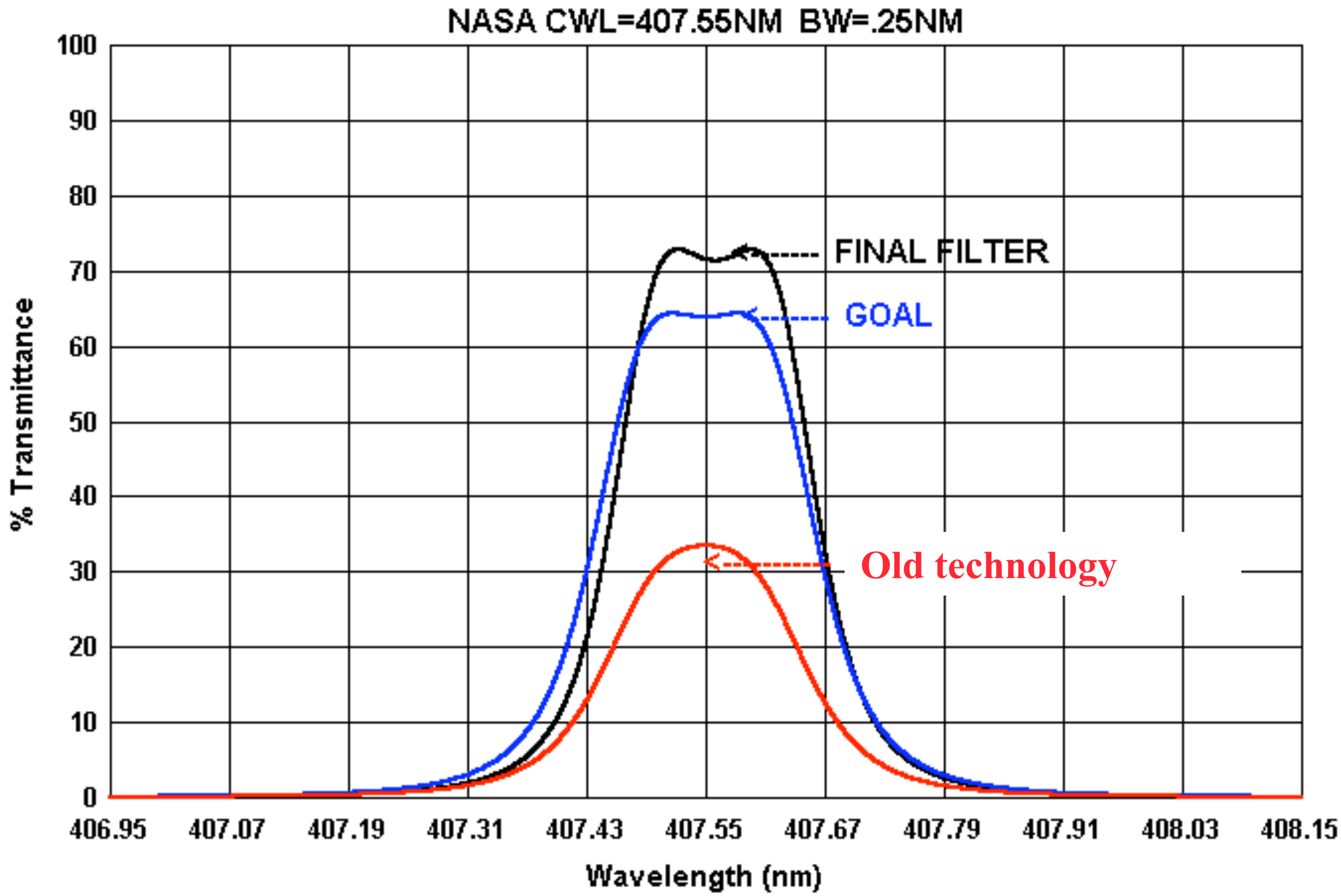


Result for 407.55/.25nm Filter



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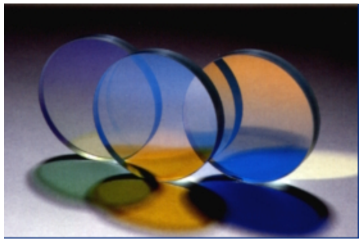
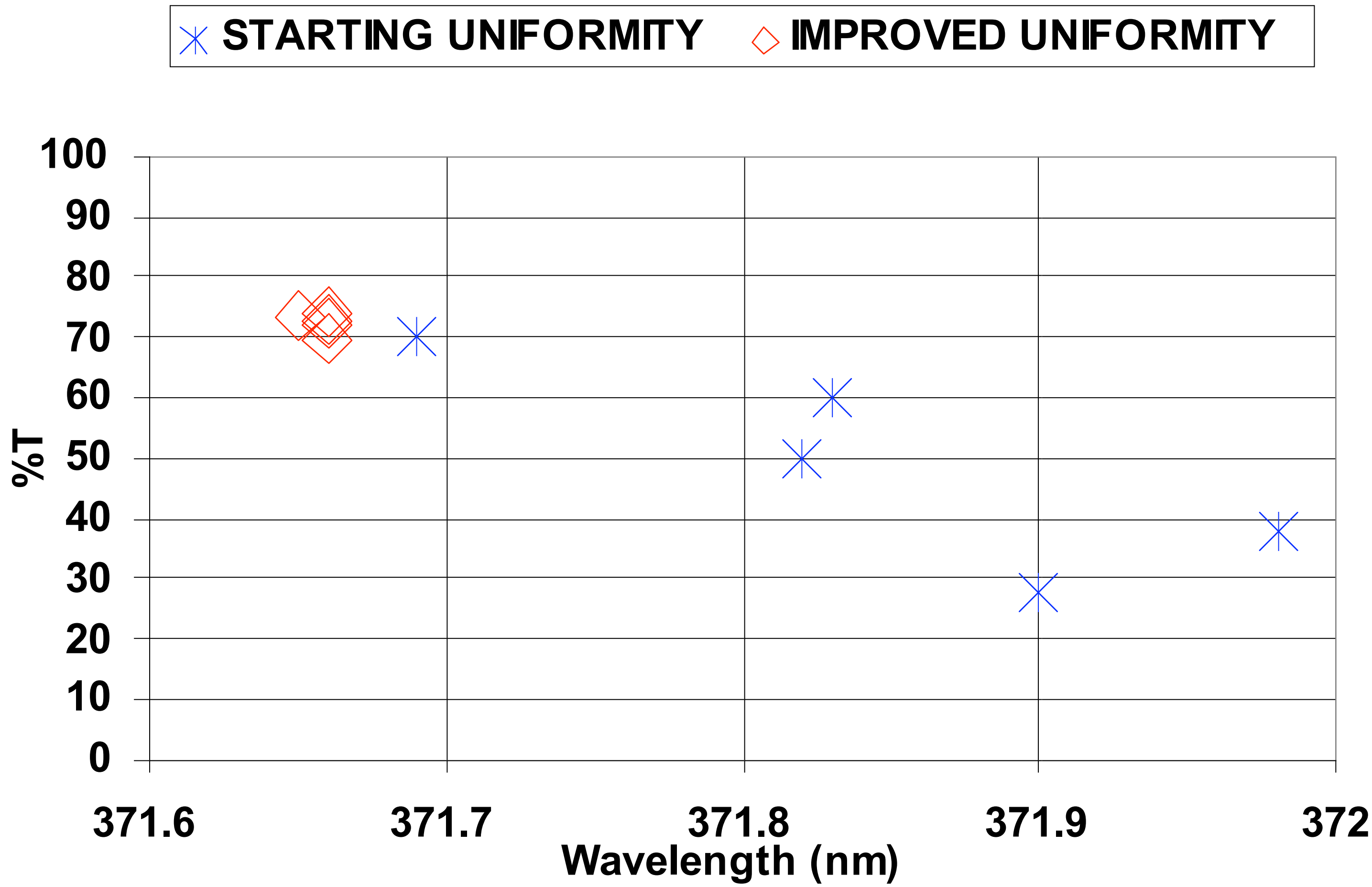
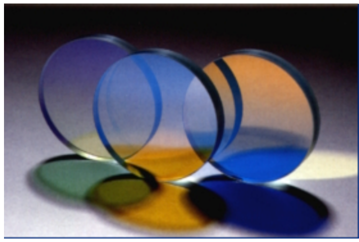


Spatial Uniformity

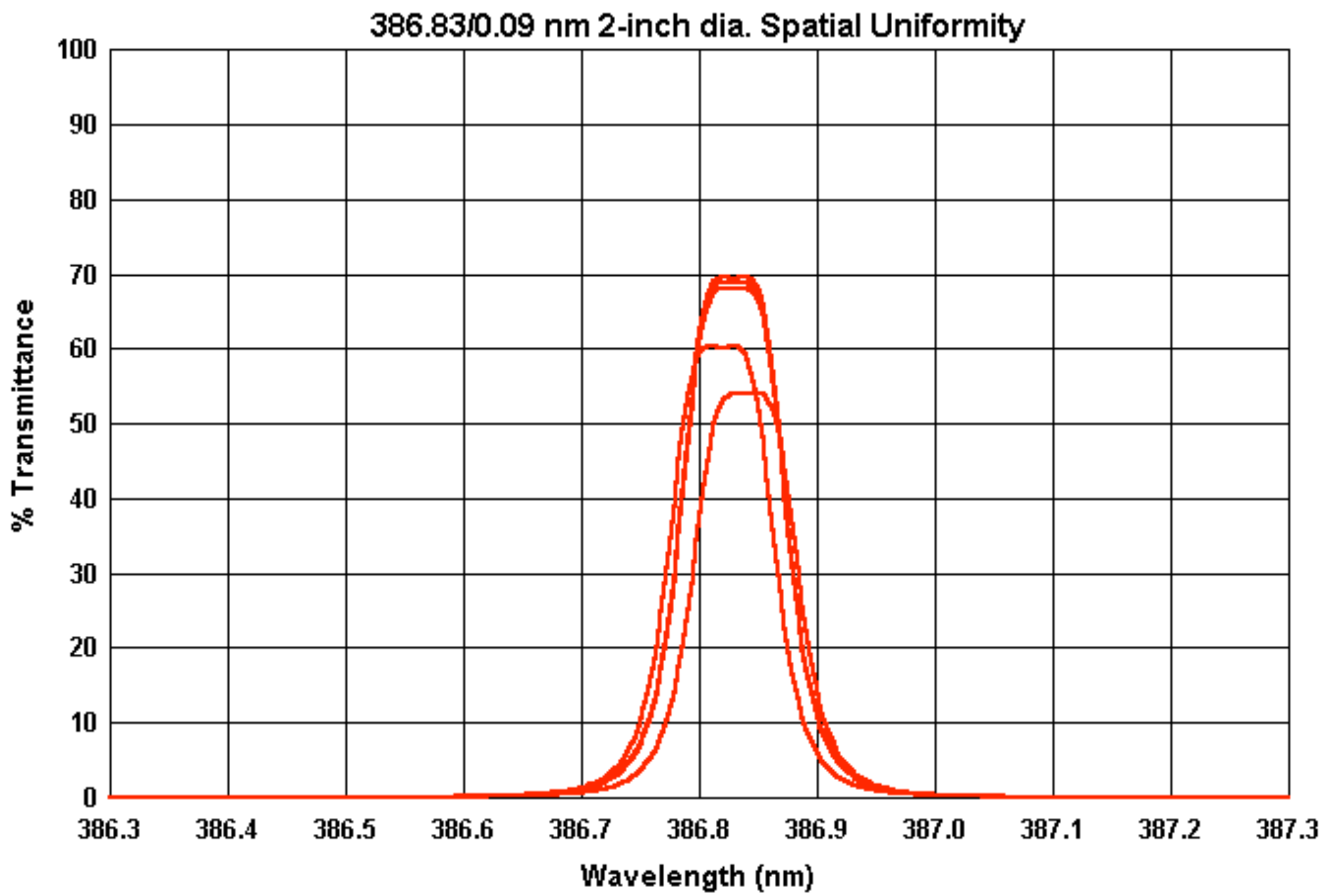
CWL ACROSS 2" DIAMETER
(371.71nm UNBLOCKED NARROWBAND)





Typical Spatial Uniformity

- %T from 54% - 70%
- Rotational Uniform < 0.01 nm
- Radial Uniformity: < 0.02 nm



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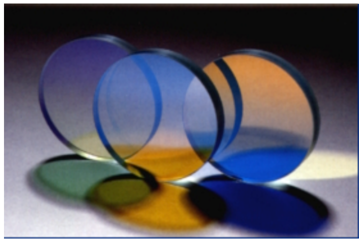
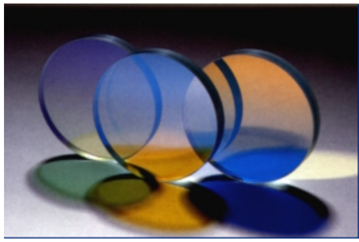


Conclusion

- Improved state-of-the-art uv ultra-narrow-bands by factor of two transmittance
- Consistent transmittance results in the 350-532 nm range
- More development to improve spatial uniformity & high optical density
- Improvements as a result of:
- identifying sources of loss,
- Developing most promising process
- Choice of substrate
- Minimizing thin film absorption in highest electric field



Pricing

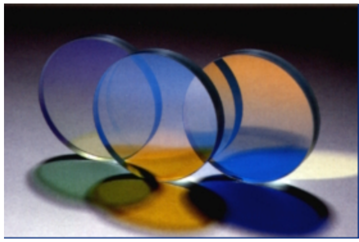
- Multi-cavity narrow band filter; blocking close to band, 2” diameter ; BW = between .10-.30nm

  $5,000 - $7,000

- 2-cavity narrow band filter; blocking close to band, 2” diameter ; BW = between .10-.30nm

  $3,000 - $5,000

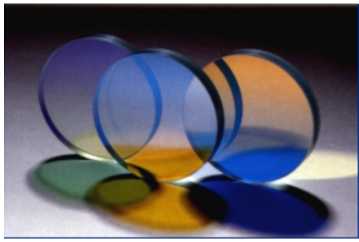
- Delivery time = within 6 weeks
- 1” diameter would be < 2” pricing



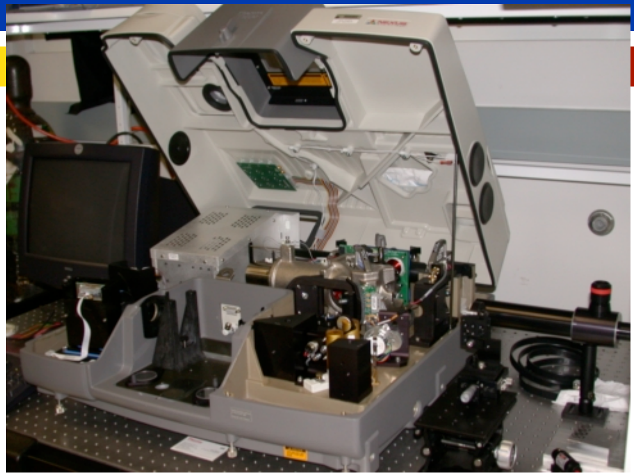
NASA/GSFC Contributions

- Characterization of filters received from Barr
  - Development of new methods of measuring center wavelength of UV interference filters
    - Assess accuracy of standard spectro-photometer measurements

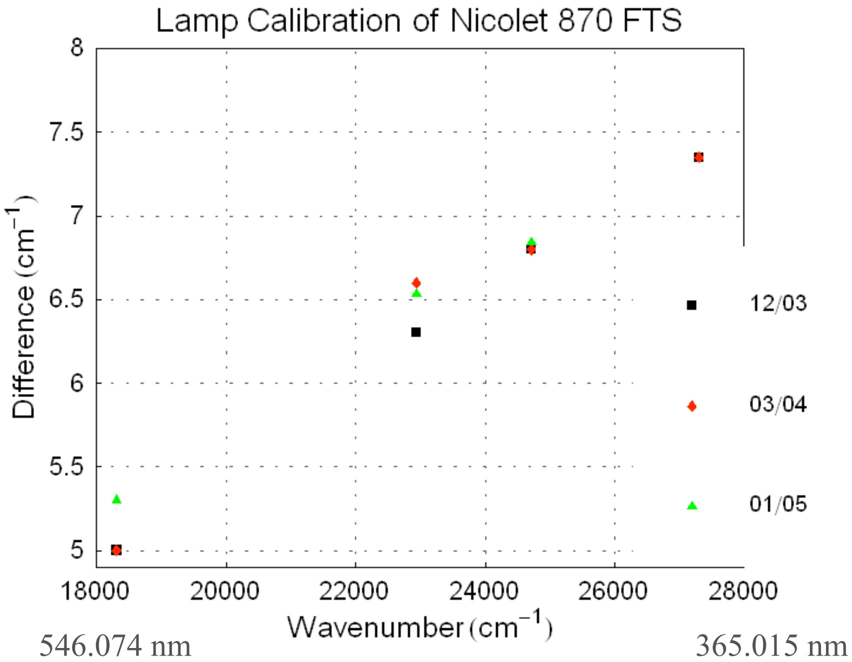
- Examples of the use of filters to improve science measurements
  - Satellite validation of water vapor
  - Nocturnal CO_2 measurements in boundary layer in and free troposphere

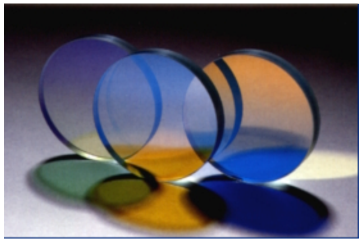


Thermo-Electron Nicolet 870 Fourier Transform Spectrometer



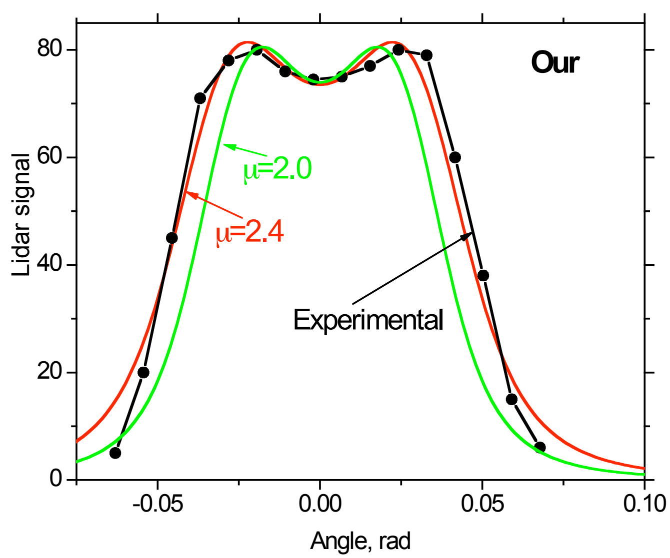
- Upgraded for UV operation
  - Internal calibration found to be 6-7cm^{-1} off for mercury lamp lines in spectral region of interest
    - Two lamps used
- Center wavelength differences of 0.02 – 0.05 nm noted between Barr and GSFC measurements
  - Differences reduced to 0.02-0.03 through this activity

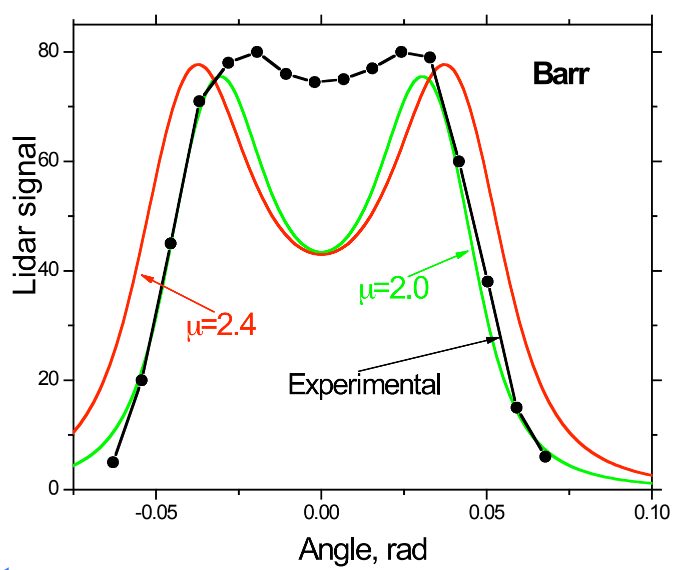




Atmospheric Validation of FTS Measurements

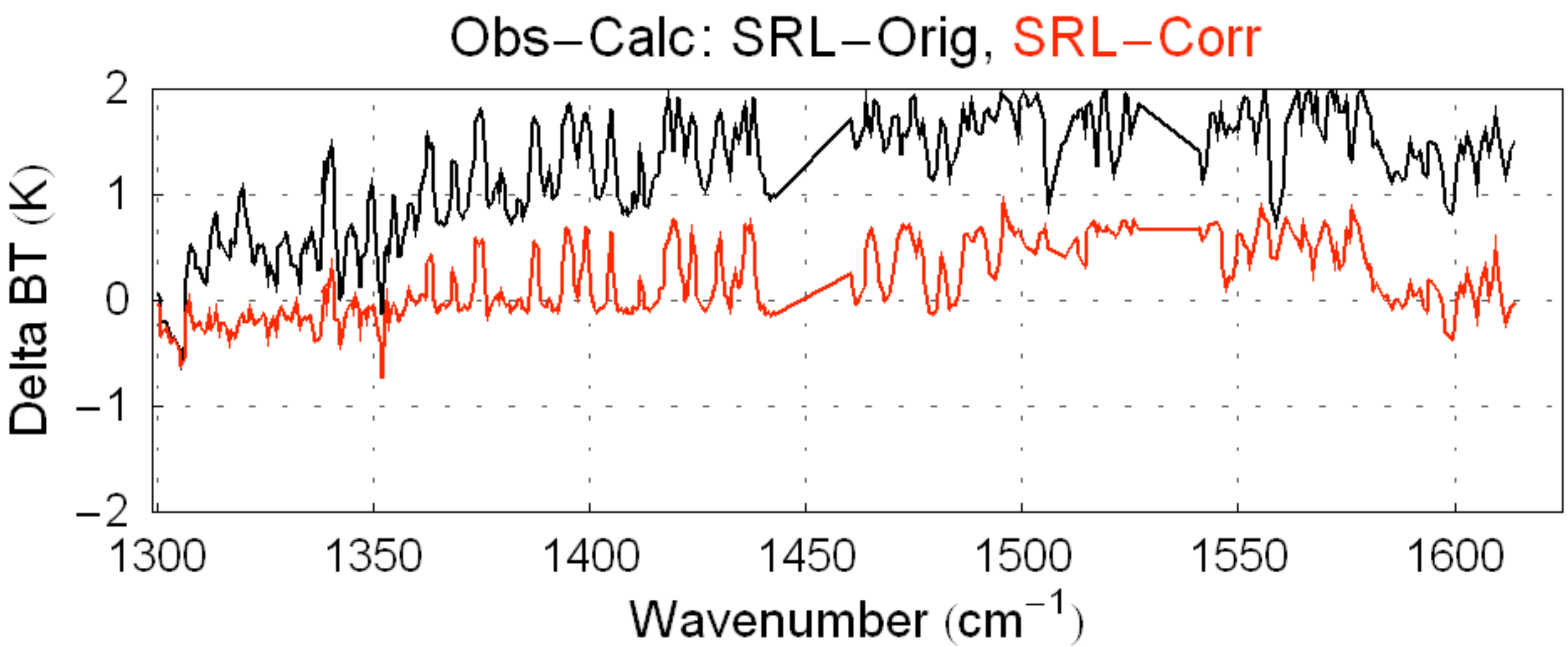
- Use atmospheric measurements of Raman N_2
  - Measure strength of Raman N2 signal versus filter tilt angle and compare with model preditions assuming filter CWL measured with FTS or spectrometer
    - Burleigh wavemeter used to verify Nd:YAG doubled wavelength
- Model predictions (red, green) using GSFC CWL (left) agree much better with measurements
- Accuracy of FTS measurements better than 0.01 nm

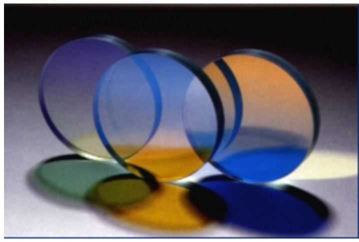




Improvements in Satellite Validation of Water Vapor

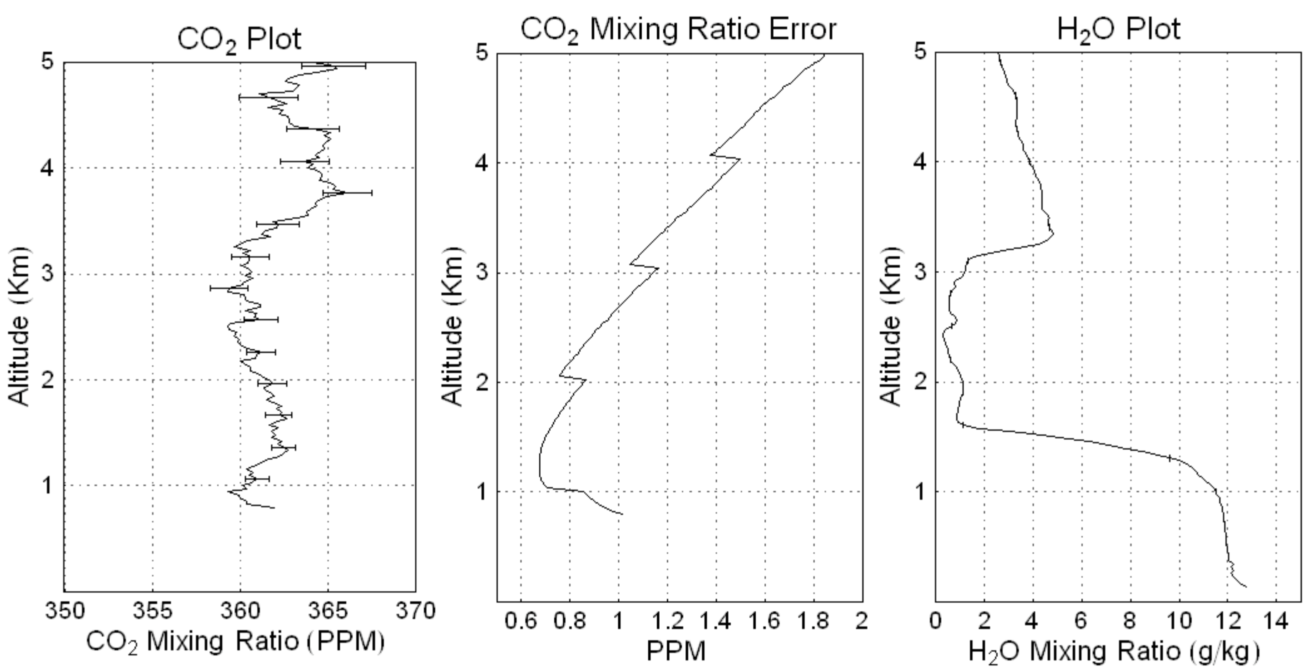
- Raman water vapor lidar measurements being added to the Network for the Detection of Stratospheric Change (NDSC) and for AURA and Aqua satellite validation
- Interference filter work done at GSFC permitted, for the first time, corrections for the temperature dependence of Raman scattering in narrow band filter measurements
- Implementation of these corrections reveals possible wet bias of 0.5K in AIRS radiance comparison shown below





Boundary Layer and Free Tropospheric CO_2 Measurements (September, 2004)

- Improved efficiency of 372 nm filter permits first demonstration of free tropospheric CO_2 measurements using ground-based lidar
- Measurements below show simultaneous measurements of CO2 and water vapor vapor
  - CO_2 signal strength agrees with model predictions



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